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Research paper

Temporal variation in export and import of virtual water through popular crop and livestock products by India

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ABSTRACT

Virtual water (VW) is defined as the water required in the production of goods. The objective of the study is to quantify the temporal variation in the virtual water trade in India from the year 2006–2016 through popular food and livestock products. Water management issues need to consider the VW trade since food production consumes large amount of water. The study was carried out using the data of exports and imports of food and livestock products of India as well as their VW consumption. Through the products considered in the study 496.9 Gm^3 and 237.2 Gm^3 of water is traded virtually in the form of exports and imports respectively during the period 2006 to 2016. The maximum export of VW were mainly through rice, maize and buffalo meat, while the imports were through cashews, pulses and wheat; rest of the food items contributing negligible amounts. This study will enable the water managers of the country to prioritize the export and import of products by considering the VW which will result in sustainable management of groundwater resources in India, which is already under threat due to climate change as well as degradation in quality due to geogenic and anthropogenic sources of contamination.

1. Introduction

Virtual water (VW) is the water consumed for producing agricultural and industrial products. This term introduced by Allan (1996) got a wide response in the fields of water resource management and food production. Increase in population in many countries, especially in Asia, necessitates the increase in food production and its corresponding water consumption. This is leading to widespread depletion in water resources in several parts of the world (Gleeson et al., 2012; Aeschbach-Hertig and Gleeson, 2012). Several other factors including failure of monsoons, deforestation and shrinking of green cover is adding to the problem of groundwater depletion. India is not an exception, where the irrigation requirements is fulfilled by 80% of groundwater which is leading to falling groundwater levels. The depletion of groundwater is evident with country's growth in the recent years due to overuse (Kannan, 2013; Bhattacharyya et al., 2015). Further deterioration in groundwater quality due to natural (Brindha and Elango, 2011; Nordstrom, 2002) and anthropogenic (Umezawa et al., 2009; Peters and Meybeck, 2000) sources has also rendered the water unusable. Efficient use of water in production could conserve not only VW but also the available water for use.

The exchange of water intensive/ extensive products from one region (production) to another (consumption) results in VW trade (VWT) (Hoekstra and Hung, 2005). Globally, the VWT for water-poor countries, proceeds with the exchange of goods from water-abundant countries to water- poor countries and vice versa. When the water availability decreases less than 1700 m^3 per year per capita, then the country is regarded as water stressed, which is time specific where people do not have access to drinking water or water for domestic use for a specific period (Falkenmark, 1986). If it falls less than 1000 m^3 per capita per year, the country is classified as water scarce (Falkenmark, 1986). A country producing goods in surplus quantities would export it to other countries and would import the goods that are produced in smaller or negligible quantities. In such a scenario, the exchange of commodities acts as a source of income for a nation. The export/import of products would indirectly also involve exchange of VW. The exporting country also exchanges water in a virtual form and the importing country thus saves water instead of investing it in food production. (Renault 2002). Middle east countries and few African countries that cannot produce food due to water scarcity thus imports food from other countries to meet the water and food demands in order to avoid conflicts over water (Allan 1992;1997;1998b;2002). Such countries export crops that require less water for production and imports food products that its population requires which is normally produced in other countries (Chapagain, 2006). From a global perspective, during a period of 10 years from 1996, it is clear that North

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Table 1
VWC of various crops and livestock products considered in this study.

Product	Virtual water content (m^3/ton)	Source
Tea	7002	Chapagain and Hoekstra, 2004; Kumar and Jain, 2007
Coffee (roasted)	14,500	Chapagain and Hoekstra, 2004; Kumar and Jain, 2007
Rice	2850	Chapagain and Hoekstra, 2004; Kumar and Jain, 2007
Wheat	1654	Chapagain and Hoekstra, 2004; Kumar and Jain, 2007
Pulses (chickpea, pigeonpea, dry beans, green peas)	3128	Kumar and Jain, 2007
Cashew	15,340	Kumar and Jain, 2007
Maize	1937	Chapagain and Hoekstra, 2004; Kumar and Jain, 2007
Groundnut	3420	Kumar and Jain, 2007
Fresh Grapes	238	Kumar and Jain, 2007
Buffalo Meat	16,482	Chapagain and Hoekstra, 2004
Sheep/goat Meat	11,879	Chapagain and Hoekstra, 2004; Kumar and Jain, 2007
Natural Rubber	7626	Kumar and Jain, 2007
Alcoholic Beverages	752	Kumar and Jain, 2007
Walnut	11,721	Kumar and Jain, 2007
Sugar (raw)	1301	Kumar and Jain, 2007
Onions (fresh)	214	Kumar and Jain, 2007

and South America, Southern Asia and Australia were the largest net VW exporters and the largest net VW importers were North Africa, Middle East, Mexico, Europe, Japan and South Korea (Allan 1998a; Hoekstra and Mekonnen, 2012).

'Water footprint', (WF) is another term that is closely related to VW. While VW is the water required to produce a commodity, a country's WF can be defined as the volume of water consumed by the country's population through the produced commodities (Hoekstra, 2003). It is further classified as green water (rain-fed, soil moisture), blue water (surface water and groundwater bodies) and grey water (polluted, waste and recycled waters). The WF contributing to the VW trade include for crops (Hoekstra and Hung, 2002; Chapagain and Hoekstra, 2004; Hoekstra, 2003; Hoekstra and Chapagain, 2007; Mekonnen and Hoekstra, 2010) and livestock products (Chapagain and Hoekstra, 2003). However, WF is not discussed in the present study.

Though, the water requirement for crops is usually high, the water requirement for producing meat and processed products conusmes 5–20 times more VW per kg than for crop products (Mekonnen and Hoekstra, 2010). The water consumed by the animal from the day it is born until its slaughter is tremendously high which includes the water required for producing its feed, drinking, cleaning and servicing the land where the animal was raised (Chapagain and Hoekstra, 2003). Likewise, crops grown at different climatic settings (arid to humid areas) has different water requirements, and hence the water consumption of animals also vary spatially for different breed varieties.

In India, the surface water availability per capita per year for the years 1991 and 2001 were 2309 m^3 and 1902 m^3 which are projected to decrease by the years 2025 and 2050 to around 1401 m^3 and 1191 m^3 respectively (MoWR, 1998). According to FAO (2016) (Food and Agricultural Organisation), through AQUASTAT, for the year 2010 it was estimated the total water withdrawal for India was 761 km^3 of which 688 km^3 (91%) were used for irrigation and livestock respectively. Studies by Hoekstra and Hung (2002) reported that India was a net exporter of VW for the years 1995–1999. Another global level study made by Chapagain and Hoekstra (2004) indicated that India was a net exporter of VW for the period from 1997 to 2001. However, Kumar and Jain (2007) have reported that India was a net importer of VW during the period of 2001–2005. The VW import and export due to major crop products for the period from 1961 to 2010 was reported by Goswami and Nishad (2015). Brindha (2017) indicated that India's net VW export has increased by 28 times from the year 1986–2013. There were significant changes in the agricultural and livestock production as well as the availability of water which was affected due to the tsunami, floods and droughts witnessed from the year 2005. It is also essential to see whether there is any change in the trade of VW in the context of widespread depletion in groundwater resources in India as reported by Aeschbach-Hertig and Gleeson (2012) and Goldin (2016). Hence it is necessary to understand the trend of variation in export and import of VW for India through the trade of crops and livestock products under the changing scenario in availability of water resources. Further it is essential to understand the changes in VW in the recent past for proper planning, development and management of the resources (Antonelli and Sartori, 2015). The studies carried out on VW trade based on the total food and livestock products is not sufficient to plan and devise strategies for sustainable development and management of groundwater in India since about 80% of agricultural and farming activities depends only on groundwater. Further, no studies have been done on the temporal variation over a long period on Indian VW import and export with respect to specific food and livestock products. Hence, the present study was carried out with the objective of assessing the temporal variation in import and export of VW through popular food products (crops and livestock) from 2006 to 2016 in India.

2. Materials and methods

2.1. Data

The annual variation in VWT in India was made based on the information available in authentic public domains. The trade data on import and export of crops and livestock products for India were obtained from sources such as Food and Agricultural Organization (FAO) of United Nations, Directorate General of Commerce Intelligence and Statistics (DGCIS), Agricultural and Processed Food Products Export Development Authority (APEDA, 2018), Coffee Board (Coffee board, 2017), The Tea Board India (Tea board of India, 2018) The Rubber Board (Rubber board of India, 2018) and Department of Food and Public Distribution (DFPD, 2018) which are governmental agencies of India. The data from these organizations were obtained from their official websites and data were collected from reliable sources for the years from 2006 to 2016. Only primary food commodities like major crops and livestock products were considered for the study except for major fruits and flowers. Thus, the food and livestock products that are primarily exported from India which are considered as popular products and is given in Table 1. Financial year (April to March) was considered for the study except for tea and coffee for which the data was obtained only for the calendar year. The minor difference between the calendar year and financial year by three months may not have major influence on the findings.

2.2. Calculation of virtual water trade

The VW exported or imported was calculated by multiplying the trade volume (ton/year) of a product with the water requirement (m^3/year) to produce that product (Hoekstra and Hung, 2002). The quantity

of VW Export (VWE) and VW Import (VWI) are calculated using the following equation

$$\text{VWE or VWI} = \text{Traded Volume (ton/year)} \times \text{VWC of traded product}(m^3/\text{ton})$$

Details on quantum of water required to produce various crops and livestock for India were obtained from Chapagain and Hoekstra (2004), Kumar and Jain (2007) and Mekonnen and Hoekstra (2012). The country's average climate data was used to calculate the VWC of crops and crop products. VWC depends on the water demand for the specific crop or livestock of the exporting country. Water intensive crops require large amount of water since cultivation. In India, traditionally rice is grown using water logging method, which requires more water than by other cultivation methods. The crop water requirement affects the VWC of crops and crop products, which could result in overestimates or under estimates (Kumar and Jain, 2007).

The VWC of an animal at the end of its lifespan is defined as the total volume of water that was used to grow and process its feed, to provide its drinking water, and to clean its housing etc., (Chapagain and Hoekstra, 2003). It also depends on various other factors like the breed of an animal, the water requirements, the climatic conditions where the feed and animal has grown, the farming system, feed consumption and so on (Chapagain and Hoekstra, 2003). The calculation of VWI was carried out based on the VWC given in Chapagain and Hoekstra (2003).

3. Results and discussion

A country's export and import mainly depends on the products consumed by the country's population. Whenever there is a demand on a product, the need for import or increase in production becomes necessary. Import and export of any food product also results in trade of water in a virtual form and revenue generation. In order to calculate the Indian VWE and VWI, the data on the quantities traded obtained from various reliable sources are taken into account.

3.1. Export and import of VW

The products that are traded in the form of exports and imports also trade water in a virtual form. The water traded can be calculated by multiplying the quantity of the product (ton/yr) with the water that was originally required for the production (m^3/ton). The VW content in the crops and livestock products were calculated accordingly and the total estimate on exports and imports during the years from 2006 to 2016 are given in Tables 2 and 3.

The annual variation in VW trade for various crops and livestock products from the year 2006–2016 are shown in Fig. 1. It has been noted that there is a decreasing trend of imports of certain products like tea, coffee, rice, wheat, groundnut, raw sugar and sheep/goat meat whereas the imports have increased for other products like cashews, walnut, grapes, onions, pulses, maize, beverages(alcoholic) and natural rubber. Similarly, the exports for various products have also increased and decreased from year to year. The exports of tea, coffee, rice, pulses, cashews, walnuts, raw sugar, grapes and buffalo meat have marginally increased while for other products the exports gradually decreased over the last ten years.

The total export of VW was 14.7 Gm^3 and total imports was 1.6 Gm^3 through tea from the year 2006–2016. In the case of coffee, the total VW export was 17.1 Gm^3 and the total VW import was 4.3 Gm^3. The VW import through coffee has increased by about 1000 times from the year 2012 whereas export has increased by 100 times from 2012. However, the details on imported quantum of coffee which is re-exported was not available.

In the case of rice, export and import of VW was 195.6 Gm^3 and 0.024 Gm^3, respectively. The total export and import of VW for wheat was calculated to be 27.2 Gm^3 and 15.9 Gm^3. The export of wheat and rice was decreasing while the import has also decreased since 2011. In the case of pulses (chick pea, pigeon pea, dry beans and green peas) the total export and import of VW was 3.79 Gm^3 and 86.1 Gm^3, respectively. The total export and import of VW through maize was calculated to be 53.2 Gm^3 and 0.49 Gm^3. Increased exports and imports in pulses were observed since 2011 while maize has shown sudden increase in imports for 2016 and decrease of exports since 2012. The data on walnut and cashew's export and import trend for the following years indicate a slight increase in exports and a constant increase in imports. The total VW export and import on cashew was 17.8 Gm^3 and 114.3 Gm^3. In the case of walnut, it was 0.65 Gm^3 export and 0.083 Gm^3 import. The total VW export on natural rubber was 0.86 Gm^3, while its total VW import was 13.3 Gm^3. The export VW for natural rubber has been decreasing whereas its import is increasing since 2011. The total export and import of VW on onions were estimated to be 5.6 Gm^3 and 0.03 Gm^3. Similarly, for raw sugar, the total VW exports were calculated to be 18.03 Gm^3 with imports in negligible amounts of 0.5 Gm^3.

The VW content on livestock products in the form of meat and its processed products have always been higher than the agricultural products. This is because the VW content for an animal is high, as explained earlier. The water consumption for different animals of different regions vary throughout the world as weather conditions, the type of environment where the animal has been raised are to be considered. The total VW export and import of sheep/goat meat is 2.397

Table 2
Export of VW for crops and livestock products from the years 2006–2016 in Gm^3/y.

Product	2006–2007	2007–2008	2008–2009	2009–2010	2010–2011	2011–2012	2012–2013	2013–2014	2014–2015	2015–2016	Total
Tea[a]	1.27	1.35	1.42	1.42	1.64	1.50	1.51	1.58	1.39	1.63	14.73
Coffee[a]	0.0047	0.011	0.0050	0.0058	0.0035	3.01	0.43	4.34	4.10	5.16	17.08
Rice	13.51	18.38	7.08	6.12	6.34	20.41	28.92	31.04	34.13	29.68	195.61
Wheat	0.077	0.00039	0.0018	0.00004	0.00057	1.24	10.78	9.2	4.83	1.02	27.15
Pulses	0.043	0.0093	0.013	0.015	0.019	0.542	0.633	1.07	0.691	0.787	3.79
Cashew	1.88	1.70	1.94	1.80	1.45	2.05	1.62	2.00	1.68	1.72	17.87
Maize	1.23	5.28	6.85	5.03	4.44	7.65	8.27	7.65	5.47	1.25	53.17
Groundnut	0.65	0.81	1.00	1.12	1.27	2.84	1.83	1.74	2.42	1.84	15.55
Grapes	0.0203	0.023	0.028	0.027	0.0307	0.0179	0.0272	0.0458	0.0255	0.0371	0.28
Sheep/Goat meat	0.058	0.093	0.441	0.535	0.169	0.129	0.177	0.243	0.271	0.282	2.397
Natural rubber	0.052	0.996	0.1	0.058	0.056	0.207	0.233	0.041	0.0076	0.0016	0.857
Alcoholic.beverages	0.013	0.017	0.019	0.015	0.027	0.019	0.029	0.234	0.199	0.18	0.756
Walnut	0.055	0.076	0.063	0.102	0.077	0.063	0.062	0.078	0.031	0.038	0.648
Onion	0.743	0.543	0.899	0.902	0.734	0.597	0.357	0.317	0.26	0.25	5.61
Sugar	0.571	3.15	1.89	0.033	0.499	1.14	1.56	3.49	3.16	2.52	18.03
Buffalo meat	n.a	n.a	n.a	n.a	n.a	16.23	17.74	23.93	24.33	23.62	105.85
Total	20.14	31.57	21.75	17.22	16.76	57.67	91.75	87.02	83.04	70.04	496.98

[a] Calendar year.

Table 3
Import of VW through crops and livestock products from the year 2006–2016 in Gm^3/y.

Product	2006–2007	2007–2008	2008–2009	2009–2010	2010–2011	2011–2012	2012–2013	2013–2014	2014–2015	2015–2016	Total
Tea[a]	0.162	0.137	0.174	0.24	0.121	0.155	0.148	0.134	0.147	0.129	1.55
Coffee[a]	0.0003	0.0007	0.0006	0.0008	0.0008	0.624	0.892	0.923	0.962	0.863	4.27
Rice	0.0004	0.0004	0.0002	0.0001	0.0002	0.006	0.004	0.0041	0.0054	0.0029	0.024
Wheat	10.05	4.42	0.0000	0.271	0.306	0.0007	0.0097	0.018	0.046	0.853	15.99
Pulses	0	0	0	0.0000	0	21.86	25.1	9.94	12.51	16.68	86.12
Cashew	8.99	9.07	9.42	11.59	6.95	12.28	12.67	12.83	14.91	15.53	114.24
Maize	0.003	0.008	0.014	0.037	0.013	0.023	0.004	0.026	0.011	0.352	0.496
Groundnut	0.0001	0.0006	0.0000	0.0013	0.0034	0.0006	0.0002	0.0003	0.0000	0.0003	0.0067
Grapes	0.0004	0.0006	0.0007	0.0005	0.0006	0.0009	0.0009	0.0035	0.0048	0.0048	0.018
Sheep/Goat Meat	0.0000	0.0002	0.0002	0.0004	0.0002	0.0001	0.0005	0.0007	0.0009	0.0003	0.0039
Natural rubber	0.0026	0.0009	0.0033	0.0169	0.0058	1.63	20.03	2.74	3.37	3.49	13.28
Alcoholic Beverages	0.0075	0.0107	0.0139	0.013	0.0153	0.027	0.025	0.076	0.12	0.212	0.523
Walnut	0	0.0000	0.0000	0.0000	0.0000	0.0003	0.0003	0.002	0.015	0.064	0.083
Onion	0	0.0000	0.0000	0.0003	0.0029	0.0038	0.0000	0.0038	0.0000	0.018	0.0298
Sugar	0.0002	0.0004	0.501	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.502
Buffalo Meat	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	–
Total	19.23	13.67	10.14	12.18	7.42	36.64	40.87	26.72	32.12	38.23	237.21

[a] Calendar year.

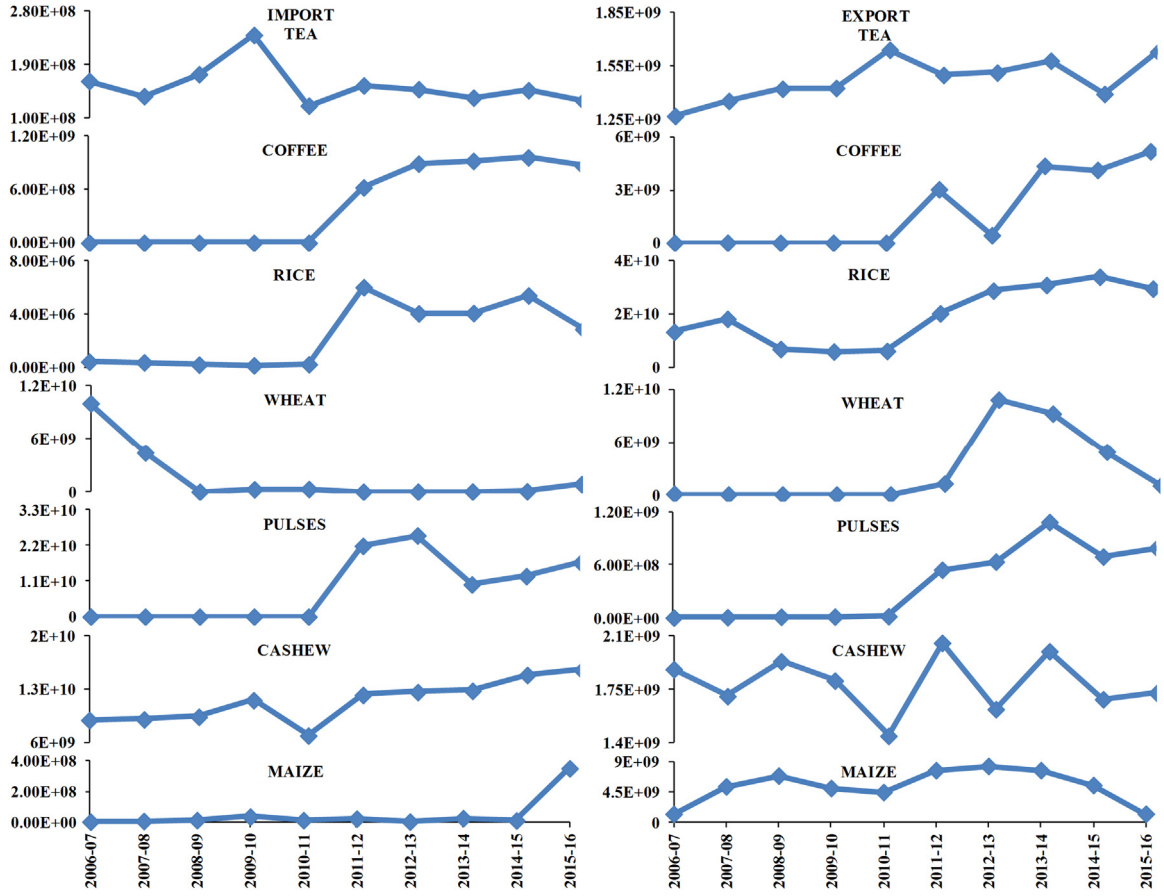

Fig. 1. The variation of VW flows (Gm3/ton) for primary food crops through imports and exports for the years 2006–2016.

Gm^3 and 0.029 Gm^3 respectively. The export and import statistics of VW based on sheep/goat meat indicates a decreasing trend in imports since 2014 and a gradual increasing trend for the year 2016. India is one of the leading exporters in buffalo meat with total VW export of 105.85 Gm^3. The import of buffalo meat has been very less compared to other meat products. India is mainly an exporter of livestock products than importing them.

Meat export plays a huge role in generating revenue. The consumption of meat has tremendously increased due to the advent of western culture and the recent economic growth of the country. The meat consumption can also be attributed to different religions, culture, tradition and urbanization (Devi et al., 2014). Slaughter houses introduced by the British East Indian company set the base for meat industry in India. Since then, the export of live animals, animals for meat and secondary products started. With information technology sectors growing and food industry showing great development, it had also led to import of various food items that cannot be produced in the country. Overall the total VW exports through crops and livestock products were calculated to be 496.9 Gm^3 and the total imports to be 237.2 Gm^3 for the years 2006–2016.

Table 4
Net export/import of VW in Gm^3/y.

Year	Total virtual water import in Gm3/ year	Total virtual water export in Gm3/ year	Net virtual water export in Gm3/ year
2006–2007	19.23	20.14	0.91
2007–2008	13.67	31.57	17.9
2008–2009	10.14	21.75	11.61
2009–2010	12.18	17.22	5.04
2010–2011	7.42	16.76	9.34
2011–2012	36.64	57.67	21.03
2012–2013	40.87	91.75	50.88
2013–2014	26.72	87.02	60.3
2014–2015	32.12	83.04	50.92
2015–2016	38.23	70.04	31.81
Average	**23.72**	**49.69**	**25.97**

3.2. Net import and export of VW

In order to assess the net export and import of VW, the total exports and imports were first analyzed. The difference between the total export/import per year gives the total net export/import for that year.

The total export of VW for ten years from 2006–2016 were calculated to be 496.9 Gm^3. The highest contributors in VW export was through rice, with 195.6 Gm^3, followed by buffalo meat with 105.85 Gm^3 and then by maize, with 53.2 Gm^3. Similarly, the import of VW for the years from 2006–2016 was calculated to be 237.2 Gm^3 from other countries. The highest contributor in the import of VW was by cashews, importing 114.24 Gm^3, followed by pulses with 86.12 Gm^3 and then by wheat with 15.9 Gm^3.

India has exported 496.9 Gm^3 of VW with an average of 49.69 Gm^3/year and imported 237.21Gm^3 of VW with an average of 23.72 Gm^3/year (Table 4). From these calculations, it is understood that India has become a net exporter of VW with an average of 25.9 Gm^3/year with respect to crops and livestock products from the years 2006–2016 (Fig. 2). This is also reflected by the depletion in groundwater resources of the country (Goldin, 2016). Whereas, India was a net importer of VW in the years 2001–2005 with an average net import of 25.93 Gm^3/year (Kumar and Jain, 2007).

3.3. Causes of net annual variation in export and import of VW

The net annual variation in export and import is due to many factors such as water availability which in turn is controlled by climate patterns, nature of the land area including the soil parameters, evapotranspiration rates, etc. India, being a very diverse country with varied weather patterns throughout, is characterized by arid and semi-arid regions (Ercin and Hoekstra, 2014). The country receives an average rainfall of about 4000 km^3 in a year with monsoons contributing nearly

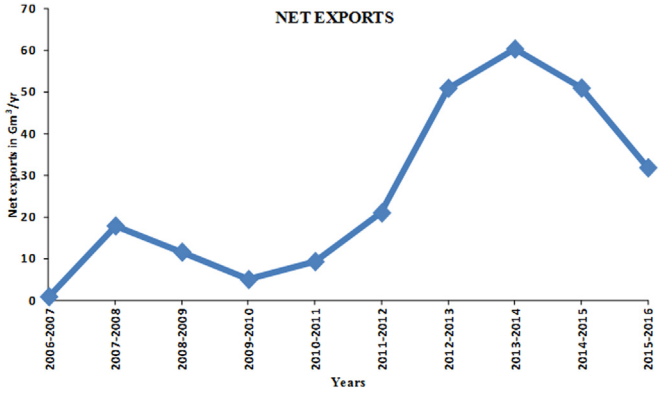

Fig. 2. Net exports of VW through crops and livestock products from the year 2006 to 2016.

3000 km^3 (Kumar et al., 2005). The south-west monsoon and north-east monsoon brings more rainfall during the months of June to September and October to December. Spatially there is a wide difference in the pattern of rainfall across the country where certain regions in the north eastern part of the country receives about 3400 mm/a and some parts in the west receives only about 400 mm/a. The source of water through rainfall plays a dominant role in the production of food products. Failure of monsoons or delayed monsoons and deficit rainfall affects the crop production, leading to import of food products from other countries. According to Intergovernmental Panel on Climate change (IPCC) 2001, India is likely to experience short-term higher precipitation intensity and long-term dry days. Shah (2008) reported monsoonal crops would experience greater risks against flood as well as droughts and summer crops would experience high evapotranspiration due to increase in temperatures. This necessitates frequent irrigation for better crop yield thus contributing to more VW inputs.

In the context of climate change, it is expected that the export of agricultural and livestock products will lead to trade of much larger amount of VW. Over exploitation of water for increased production of certain important crops like rice, wheat and their exports lead to a maximum trade of VW. Countries like India that concentrates on 'self-sufficiency' in food as a national priority will try to produce more crops to feed the country's ever-growing population (Gupta and Deshpande, 2004; Kumar and Singh, 2005). Water is used in large quantities (considering the evapo-transpiration rates and the weather patterns for different areas across the country) more than the crop actually requires for its growth. The crops produced in hot arid to semi-arid regions will require more water than the crops grown in regions with moderate climate. The net change in annual VW also differs based on the area of production, the final production rate, export and its import. The net export value of a particular crop product increases when it is easily produced in a surplus quantity. From the data, it may be inferred that rice was exported the most and then followed by other crops like maize, wheat, pulses, sugar, cashew, coffee, etc. India is also a leading exporter of livestock products, especially buffalo meat, but with less quantity of import from abroad.

4. Conclusion

Studies on VW trade based on the total food and livestock products is common, however in this study temporal variation in VWT of some significant agricultural and livestock products exported from India was brought out from a period from 2006 to 2016 which would be useful to plan and devise strategies for sustainable development and management of groundwater in India since about 80% of agricultural and farming activities depends only on groundwater. India has exported on an average of 49.69 Gm^3/y and imported 23.72 Gm^3/y of VW, thus becoming the net exporter with an average of 25.9 Gm^3/y for the years 2006–2016. As about 80% of agricultural activity in India depend on groundwater usage, depletion of this resource is evident over the recent decades. Considering increasing trend of population growth, food production cannot be reduced in order to conserve water as water consumption and food production are interdependent. The high export of certain food products is related to overexploitation of groundwater. Increase in VWE in future will lead to further decline in groundwater resources in spite of enormous measures taken by various agencies to overcome this problem by aquifer recharge measures. It is important that the foods be produced in sufficient quantities, according to the needs, and in calculative quantities for export, through stringent measures to reduce the use of water and produce more. Production of water efficient crops could bring income and at the same time would make us rely more on imports. The agricultural and livestock products that are produced by stringent water efficient methods especially the products such as rice, maize, buffalo meat etc only may be encouraged for export. Beef export and production should also be reduced, since India is one of the top producers and export of beef and VW in beef production

is generally high. The VW trade only through food products has been made in this study. Not just the agricultural industry depends on groundwater but also other industries like chemicals and fertilisers, leather products, automobiles, spare parts, mining, textile, etc. However, the use of groundwater for agricultural and farming purpose is about 85% and the remaining only is used for industrial and domestic purposes. Hence the only way out to reduce the export of water in virtual form from India is through the production of food products by water efficient methods. Water efficient methods include effective irrigation techniques, proper irrigation scheduling, suitable crop selection according to the land, climate conditions, soil type and water availability; using alternative sources of water for irrigation. Opting for dry crop practices in places with less availability of water is strongly advised against water consuming crops on the same area. Judicious mixing and growing of different crops with lower water demand at the national level need to be taken up to reduce the export of VW from India especially under the present scenario of wide scale depletion in groundwater resources and climate change induced rainfall variability. Erratic monsoons, droughts, floods, increase in population, increase in mean atmospheric temperature, depletion of groundwater resources will intimidate food and livestock production. In this scenario, the need to keep up with the demand for export, the producers will be forced to increase groundwater exploitation which will threaten the sustainable development goals of the country. This study on the temporal variation in VWT will enable the water managers of the country to prioritize the export and import of products by considering the VW which will result in sustainable management of groundwater resources in India, which is already under threat due to climate change as well as degradation in quality due to geogenic and anthropogenic sources of contamination.

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